The University of Hong Kong
Department of Computer Science

Final Year Project - Project Plan

Blockchain System for 5G Network Sharing

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1 Introduction

The emergence of 5G network has been expected to lead the forthcoming revolution of mobile technology. Targeting to reach high speed and low latency, 5G technology has shown its potential to change the meaning of mobile usability with a huge array of new applications [1]. At the same time, the growth of infrastructure cost will inevitably bring serious challenges on the investment strategy and future profits for mobile operators, as the range constraint of 5G base stations requires denser constructions [2]. To deal with this issue, infrastructure sharing [3] is considered as a potential cost-saving strategy to solve the practical roadblocks of 5G deployment. Although sharing network has been applied among some operators even before the emergence of 5G, this type of cooperation only occurs within a small groups of mobile operators regionally [4].

This project proposes a blockchain-based system that empowers network sharing in a global scope. With the ability to form consensus among distributed nodes on verifiable records, blockchain [5] has the ability to consolidate the trust base of different network operators so that it is a potential platform for achieving necessary functionality required by network sharing. For this project, our work will be carried out on two layers. On the protocol layer, a consensus protocol using sharding [6] technique will be designed to guarantee the high efficiency of the system. On the application layer, a smart contract [7] will be implemented to contain the operation logic and needed functions that facilitate the cooperation of operators across regions.

2 Background

This section provides an overview of the background knowledge needed for the blockchain implementation for the 5G telecom base station sharing, including the potential and constraints of 5G network, current development and usage of telecom infrastructure sharing and the applicability of blockchain as a solution.

2.1 Overview of 5G Network

5G network, which stands for the fifth-generation cellular network, is a digital cellular network significantly evolved from previous generations allowing mobile devices to communicate with each other efficiently in areas covered by the wireless telecom signals. Compared with previous generations, equipped with a larger bandwidth, 5G will deliver high information transfer rates, ultra-low latency, massive capacity, and more uniform user experience [1]. This improvement in the performance will elevate the mobile network to not only enhance the connection between people, but also interconnect machines, objects, and devices, and further empower new user experiences and boost new industries.

However, there are costs come behind the acceleration of the network. As 5G network is achieved with high frequency waves, such as millimeter waves, the energy in this high frequency waves decays much faster while spreading than the energy in the lower frequency waves which are used in previous generations. This makes the coverage zone of each 5G network base station smaller than the previous generations' network base station [8]. In the previous generation, the service area covered by telecom infrastructure radio waves is typically divided into small geographical areas, and the area covered by a single base station is called a cell. Inside each cell, the mobile devices are connected with the telecom base station through wireless radio waves, and the telecom base station is further connected with the telephone network and the Internet server by a high bandwidth optical fiber or wireless backhaul connection. When it comes to 5G, the cell size has to be smaller in order to maintain a stable wireless connection from mobile devices to the telecom base station [9]. This decrease in the cell size urges the base station to be more densely deployed, which further causes a rise in the construction cost.

In order to avoid the increase in the construction cost, sharing telecom infrastructure among telecom operators is a solution, and in this report, we will present a way to feasibly implement the telecom infrastructure sharing for 5G.

2.2 Telecom Infrastructure Sharing

The telecom infrastructure sharing is defined as the process by which two or more telecom operators can deliver their mobile service to the end clients through shared infrastructures. It includes the sharing of passive elements of network infrastructure (cabinet, site, power, etc.) and sharing of active elements in the radio access network (antenna, radio network controller, etc.) [5]. Through the sharing of the telecom infrastructure, the operators can save the cost of deploying and maintaining the infrastructure, while at the same time keep their service widely spread and cover a large geographic area. Nowadays, there are several practices of telecom infrastructure sharing in Europe regarding 3G and 4G. For example, there are active sharing with joint deployment of infrastructure based on the agreement of all the parties in the sharing in UK, Spain, and Sweden. However, one challenge related to this agreement based infrastructure sharing is that there are confidential and commercially sensitive information between competitors. If the information is not assessed carefully, it can present risks of collusion or privacy leak between the sharing parties. In this case, the robustness and reliability of the sharing is a large concern.

The potential shortcoming of the current telecom infrastructure sharing motivates the use of blockchain to increase the trust between the sharing parties as well as the trust from the public.

2.3 Overview of Blockchain

The blockchain technology is designed to create distributed systems that are used to record transactions among parties without a central authority. It is essentially a growing list of records called blocks that are linked using cryptography so that the transactions recorded on the chain are verifiable and resistant to modification. Without the use of a centralized third party, the proposed solution to ensure the validity of records is that all transactions must be publicly announced and all users reach consensus on a single history of all transactions [5]. Thus, various consensus protocols have been proposed to guarantee the security and reasonable performance of the blockchain systems in different scenarios, such as Proof-of-Work (PoW) and Proof-of-Stake (PoS).

With the ability to form consensus among users who share no trust base, blockchain has shown the potential to accommodate various distributed applications. Ethereum, as the most used general-purpose blockchain, has built its runtime environment Ethereum Virtual Machine (EVM) for smart contracts, which are used by developers to program their own functionalities. Smart contracts are high-level programming abstractions that can be compiled to EVM bytecode and deployed to blockchain for execution. For developers, they can simply use one of the smart contract languages to create and publish applications that will run inside Ethereum [10].

To empower deployments of general applications, an ideal public blockchain should be highly efficient, from the aspect that its throughput and energy consumption of processing transactions should be comparable to those traditionally centralized services (e.g., Visa processes about 2K transaction/s). However, despite much efforts, existing blockchain consensus protocols cannot efficiently process transactions with strong consistency. It is known that Ethereum can only process less than 20 transactions per second on the main chain and the average time it actually takes for a transaction to be added to the blockchain is 1.2 minutes.

3 Objective

The objective of this project is to build an efficient, consistent and scalable blockchain system that empowers the sharing of network infrastructures among 5G operators. The scope of this project includes smart contracts performing the operation workflow of network operators and a newly proposed consensus protocol using the sharding technique.

4 Methodology

This section presents the technology and platform we will use to build the model, including the protocol level and the application level. It also describes the testing methods for its feasibility and overall performance.

4.1 Protocol Level: Blockchain Sharding

As a public ledger where all digital events execute, blockchain is bloated with huge total traffic and a large number of independent participants involved, since it requires the whole record to be acquired by all nodes. Sharding is one of the ways to solve this problem. By the sharding technique, the mining network is uniformly and securely partitioned into multiple committees, each group of nodes handled in parallel [11]. Some sharding protocols have already been proposed these years, such as RapidChain, a $\frac{1}{3}$-resilient sharding based protocol [12].

In our project, the base stations built by telecom operators will be regarded as nodes in the blockchain system. Nodes representing base stations in the same region will be placed in the same shard. A shard functions as a group. Every group chooses a group leader randomly after formation, which takes the responsibility to gather all data consumption information. Within each shard, all honest nodes run internal group consensus to decide whether to accept or reject a record. A final block in each shard is generated and broadcast to the whole network on its level during a certain time period [6]. The data consumption record will be aborted if not all shards are willing to commit it. In addition, the sharding system is hierarchical. In a larger geographic area, a shard will be set at a relatively higher level, which will take charge of some shards in a smaller scope. When a user connects to the network, the consensus will be done among the lowest-level data centers first, and settlement of different regions is sharded and managed by higher-level data centers. Settlements of shards on different levels are done with different time intervals, and the main chain will be updated at the slowest rate.

When a user connects to the base station in areas managed by another blockchain shard, the record will affect the ledger states held by two or more distinct shards. This is when cross-shard transactions occur. As validators have been divided into different shards and each group of validators only process transactions within its own blockchain shard, the cross-shard transactions cannot be processed by validators on a single shard. Two types of approaches can be considered to solve this issue. The synchronous approach is that whenever a cross-shard transaction occurs, new blocks in multiple shards which contain the state transition related to that transaction are proposed at the same time. Then validators from different shards collaborate to execute these transactions. The asynchronous approach is that each shard process its half once it has sufficient evidence that the other shard has executed its portion. However, a possible flaw is that the transaction is only partially applied, as successful adding to both shards cannot be guaranteed. Therefore, careful designs are required to maintain the atomicity of system. In this project, a suitable mechanism will be implemented to handle this issue.

Sharding benefits the distributed ledgers in terms of scalability. We aim to design such a system without the tradeoff of transparency, auditability or security. It will offer a competitive alternative to the prevailing blockchain system with high overhead.

4.2 Application Level: Smart Contract

To develop an end-to-end application, a smart contract is used to implement business logic. The business logic includes but not limited to the creation of a service plan through operators and the subsequent use of them in agreement by their counterparties. To be more specific, the user information is shared among all telecom operators and will be stored in a cloud server. When data is recorded, the user's ID, as well as the data cost will be saved in the blockchain. Each telecom operator behaves in a similar way, extracting information from the blockchain periodically and calculating the data cost by each person. It will treat the cases differently for users selecting distinct service plans and for users connecting different base stations. The database will be updated after the user paying his bill or changing the service plan. We will apply the global decentralized platform, Ethereum, as the smart-contract system, on which the sharding program mentioned in 4.1 is based. The contract-oriented language Solidity will be used as enactment, as it is high-level, kind of similar to Javascript, and can be compiled into EVM bytecode [13]. As for the frontend part, we will import the software library Web3.js to connect the user-accessible GUI to its backend blockchain. Web3.js is a Javascript library that can interact with Ethereum [13]. It allows developers to read and write data to the blockchain network by making requests to a node via JSON Remote Procedure Call (RPC). Hence, telecom operators will be able to 'talk' to the Ethereum Blockchain and set the service plan and data calculation schema on their own.

5 Schedule

Time Periods	Tasks
Sep., 2019	Literature Review: • 5G network • Telecom infrastructure sharing
	Phase 1 Deliverable: ***• Detailed project plan*** ***• Project website***
Oct. - Nov., 2019	Related Work Review: • Blockchain smart contract • Blockchain sharding
	Application Level Design: • Consensus on network data usage • Consensus on client data sharing
	Protocol Level Design: • Sharding mechanism
Nov. - Dec., 2019	Implementation on Ethereum: • Application & protocol Level
Jan. - Feb., 2020	Testing of Implementation: • Server and client simulation • System performance evaluation
	Phase 2 Deliverable: ***• First presentation*** ***• Preliminary implementation*** ***• Detailed interim report***
Mar., 2020	Refinement to the Implementation: • Performance re-evaluation • Formating and documentation
Apr., 2020	***Phase 3 Deliverable:*** ***• Finalized tested implementation*** ***• Final report*** ***• Final presentation***
May - Jun., 2020	Project Exhibition and Competition

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